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Translation of "Tokovyye Sistemy Letnego Sezona v Pripolyusnoy Oblasti," Institut Zemnogo Magnetizma, Ionosfery i Rasprostraneniya Radiovoln, Academy of Sciences USSR, Preprint No. 13, Moscow, 1973, 21 pp

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 DECEMBER 1973

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ABSTRACT: The space-temporal distributions of magnetic variations on $\phi' > 70°$ in the summer are presented for various orientations of Y_{SE}, the azimuthal component of the interplanetary magnetic field in the plane of the ecliptic. It is shown that for $Y_{SE} < 0$ (from the evening side to the morning side), there exists in the daylight sector a strong westward current in the form of a spiral on $\phi' \sim 83°$ at 18^h, $\phi' \sim 82°$ at 12^h and $\phi' \sim 75°$ at 9^h. There exists in the daylight-evening sector a vortex with counterclockwise current and focus on $75° < \phi' < 78°$. For $Y_{SE} > 0$ the counterclockwise vortex embraces practically the entire polar cap and is compressed on the evening side at $\phi' \sim 74°$ and on the morning side at $\phi' \sim 85°$. The focus of the vortex is located at the 15^h meridian at $78° < \phi' < 80°$.

The existence of peculiar variations of the magnetic field in the polar region has been the subject of lively discussion in recent literature. A systematic review of the findings is presented in [1, 2]. The discovery that the aforementioned variations are closely related to the azimuthal component of the interplanetary magnetic field in the ecliptic plane (Y_{SE}) represented a new impetus to investigation of these variations [3, 4]. /4*

Information that is available in the literature concerning the current system responsible for the variation in the polar region is extremely contradictory. For the Northern Hemisphere [5] it is a zonal ionospheric current system with maximum current density at $\phi' \sim 80°$ in the daytime and focus in the vicinity of the geomagnetic pole; the zonal current flows westward with sectorial structure of the interplanetary magnetic field (SSIMF) facing the sun ($X_{SE} > 0$); $Y_{SE} < 0$), and eastward with the SSIMF facing away from the sun ($X_{SE} < 0$, $Y_{SE} > 0$). In [6] it is a zonal current flowing eastward around the geomagnetic pole with the SSIMF away from the sun and the absence of zonal

*Numbers in the margin indicate pagination in the foreign text.

current with the SSIMF toward the sun. In [7] it is a vortex with counterclockwise current in the afternoon hours and the focus between $\phi' \sim 81°5$ and 86° with SSIMF away from the sun, a narrow band with a westward current in the form of a spiral, beginning in the daytime sector at $\phi' \sim 86°$ and descending into the lower latitudes toward the morning hours with the SSIMF toward the sun. According to [8, 9], in the polar region there flows along the corrected geomagnetic latitude of ~80° an eastward zonal current with the SSIMF away from the sun and westward current with the IMF toward the sun, but confined to the daylight sector only. A westward current, flowing along the auroral oval, and a counterclockwise vortex on the daylight side of the earth, similar to one proposed previously [11], but displaced in latitude during reversal of polarity of SSIMF, are used in [10] to explain field variations in the polar region. In [12] the polar variations are connected with subboreal current systems, but in [13] the system of zonal currents that flow from the west to the east appears with the SSIMF away from the sun. This variety of current systems, proposed for describing magnetic field variations in the polar region is attributed to several factors. Among them are incompleteness of the utilized data (three observatories), conclusion concerning the shape of the current system, on the basis of only one latitudinal midday-midnight cross section, failure to utilize all three components of the field of terrestrial variations, difference in the utilized level of measurement of the field variations. Also very important is the fact that all conclusions concerning the character of the currents were derived with the SSIMF facing toward or away from the sun, whereas the most recent investigations have shown a close relationship between the character of polar variations and the azimuthal (Y_{SE}) component of the IMF. /5

Examined below are the current systems in the polar region during July and August of 1965 according to hourly values of the three components of the geomagnetic field from seven observatories in the Western Hemisphere. These observatories make exhaustive utilization of observation data at $\phi' \geq 70°$, available at MTsD-B2 [World Data Centers]. Periods with $Y_{SE} > 0$ and $Y_{SE} < 0$ are examined separately. The analysis was carried out separately for all days and for all magnetically calm periods, when the daily mean AE < 150 γ. As in [4], the daily mean values for 11 July 1965 and calm winter days were used as the field reference point, and the nighttime values of the calm summer days were /6 taken into consideration. The D_{st} variation related to annular current constituted an average of 2-4 γ.

Presented in coordinates in Figures 1-4 are the corrected geomagnetic latitude and distribution times in the near-polar region of variation vectors in the horizontal ΔT (arrows) and vertical Z (numbers at the bases of the arrows) planes. The heavy lines indicate the places where the current lines are compressed, where ΔT is maximum and Z vanishes. The arrows indicate the direction of the current.

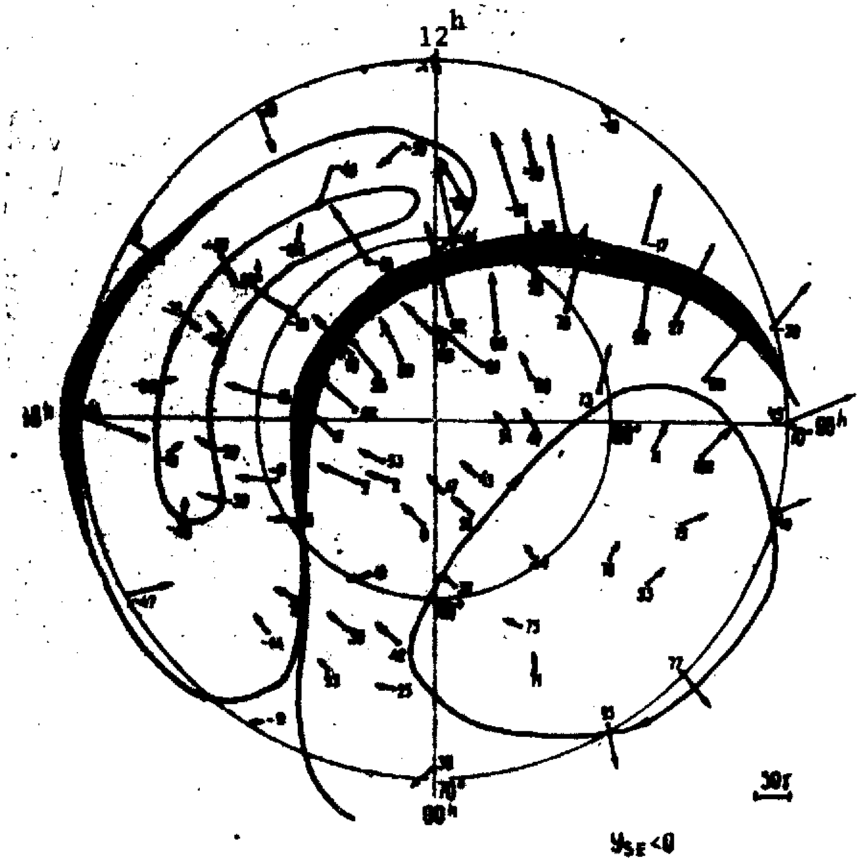


Figure 1. Polar Distribution of Variation Vectors in Horizontal ΔT (Arrows) and Vertical Z (Numbers at Bases of Arrows) Planes. The coordinate system is the corrected geomagnetic latitude and corrected geomagnetic time. The jet-like currents are indicated by heavy black lines. The arrows show the direction of the currents. The interplanetary magnetic field has a component from the evening to the morning side ($Y_{SE} < 0$). Observations for all days are used.

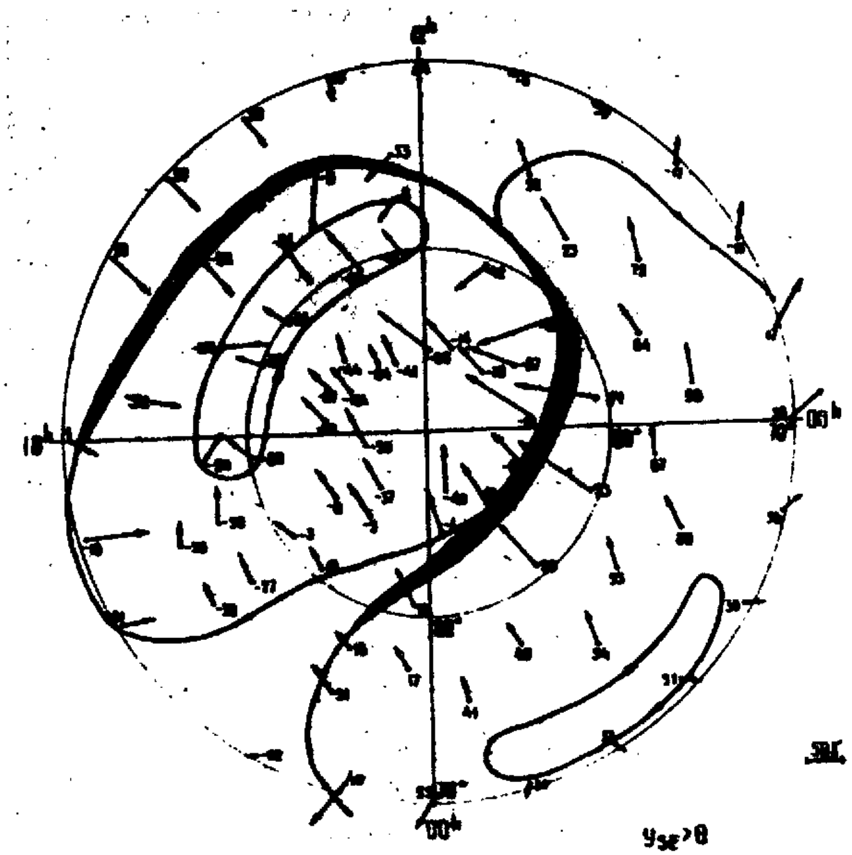


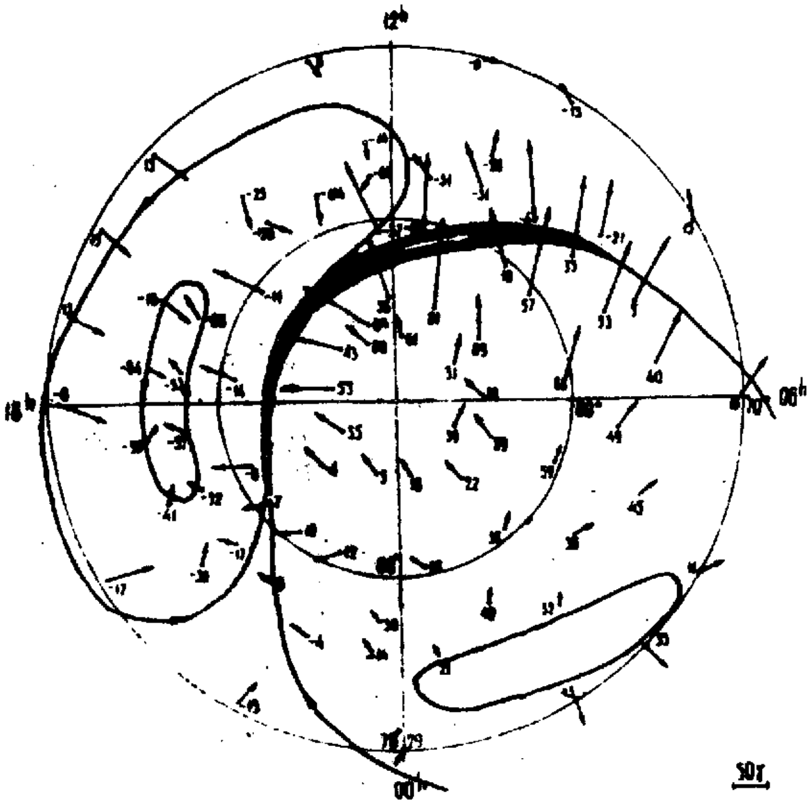
Figure 2. Same as Figure 1. Interplanetary magnetic field has morning to evening component ($Y_{SE} > 0$).

The basic features of the current systems as functions of the sign of Y_{SE} amount to the following:

For $Y_{SE} < 0$ there is a strong westward current in the daytime sector in the form of a spiral with $\phi' \sim 83°$ at 18^h, $82°$ at 12^h, $75°$ at 9^h. The current is distinct in field variations and during calm days. It is closed through lower latitudes partially through the evening and partially through the nighttime sides. In the daytime to evening sector there is a counterclockwise vortex whose focus is located at latitudes between $\phi' \sim 75°$ and $78°$ at 16 LGT. The latitude of the focus remains the same for periods with various disturbance levels.

For $Y_{SE} > 0$ the counterclockwise vortex embraces practically the entire polar cap and is compressed on the evening side at $\phi' \sim 74°$ and morning side

at $\phi' \sim 85°$. The focus of the vortex is located at $\sim 15^h$ meridian at $78° < \phi' <$ /7
$< 80°$. There is no indication of the existence of strong zonal eastward current on the daylight side at $\phi' \sim 80°$. Variations for all days indicate the closure of part of the current from the polar vortex through the nighttime sector of the auroral oval; weak distributed currents flow during the magnetically calm period on the nighttime side at $\phi' < 80°$.



$\psi_{sz} < 0$
AE < 150 γ

Figure 3. Same as Figure 1. Interplanetary magnetic field has evening to morning component. Days with AE < 150 γ are used.

Not all vectors are depicted in Figures 1-4, but only as many as are needed to indicate the most characteristic features of the current system. The showing of all vectors only complicates the polar diagram, since the vectors frequently intersect and pile up on each other. Therefore the latitudinal cross sections of the three components of the geomagnetic field are shown in Figures 5 and 6:

X', Y' -- in the direction of the corrected geomagnetic pole and eastward from it, respectively, and Z -- radially toward the earth. Shown in each cross section are X', Y' and Z of all seven observatories. The latitudinal cross sections agree satisfactorily with the distributions of the currents depicted in Figures 1-4, both in terms of all days (Figure 5), and for AE < 150 γ (Figure 6). Clearly shown is compression of the jet-like westward current at $\phi' \sim 82°$ during midday hours for $Y_{SE} < 0$ (the transition of Z through zero and peak and X'). There is no indication of the existence of an eastward current band at $\phi' \sim 80°$ in the daytime sector for $Y_{SE} > 0$. During the morning hours there is a diffuse maximum at X' and Z ~ 0 for $Y_{SE} > 0$ in the near-polar region at $\phi' \sim 85°$, which is interpreted as compression of the current lines in this region. Such compres- /8 sion, judging by the latitudinal cross section X' and Z at $3\text{-}4^h$, local geomagnetic time, is absent for $Y_{SE} < 0$.

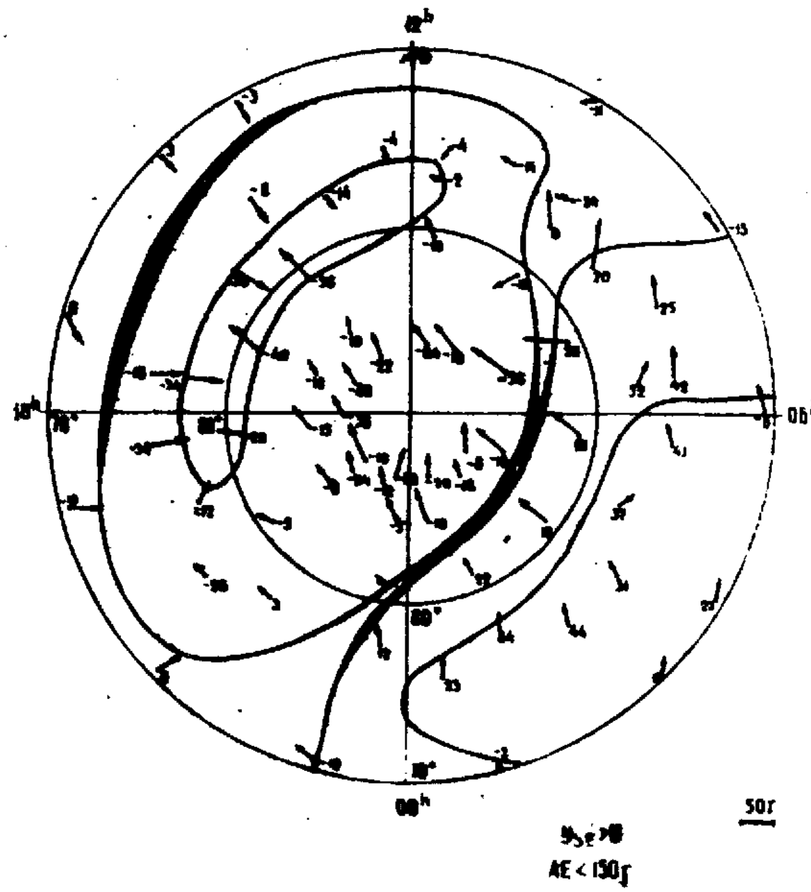


Figure 4. Same as Figure 1. Interplanetary magnetic field has morning to evening component. Days with AE < 150 γ are used.

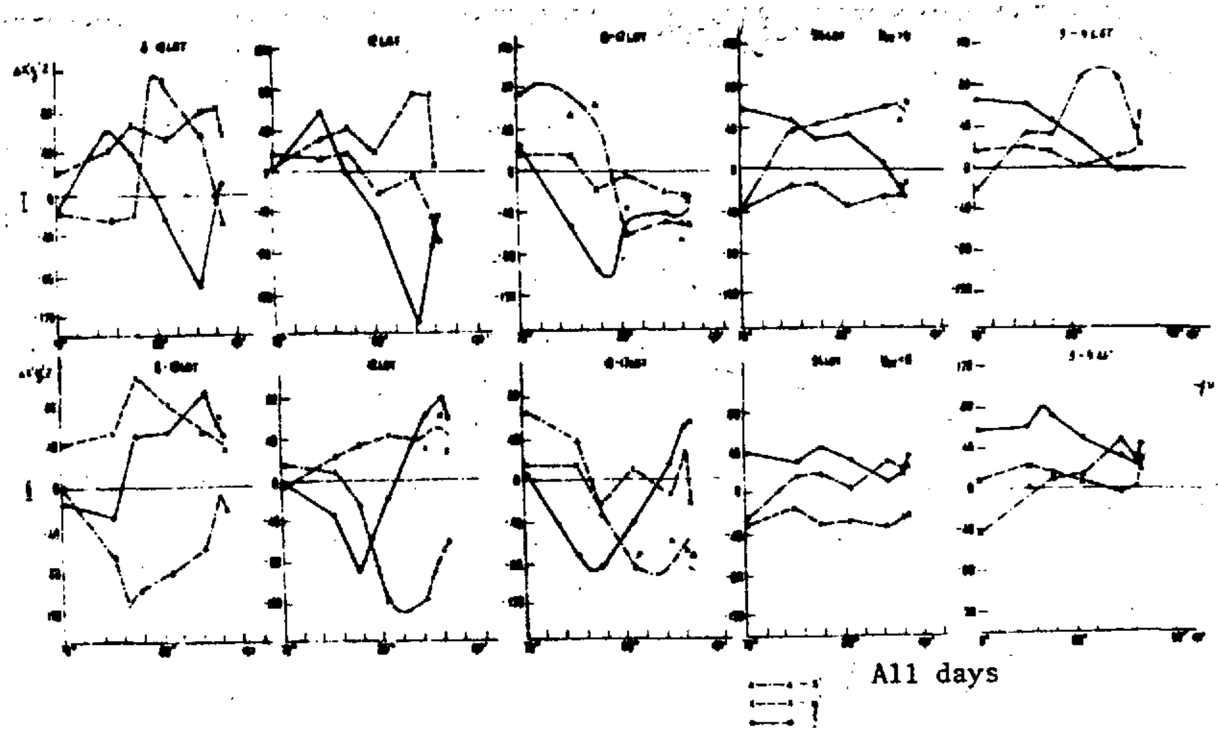


Figure 5. Latitudinal Changes of the Field of Variations of the Three Components of the Geomagnetic Field in Five Hourly Sectors: X', toward the corrected geomagnetic pole, Y', transverse to the corrected geomagnetic pole (eastward positive), Z, radially to the earth. Observations for all days are used. $Y_{SE} > 0$ above, $Y_{SE} < 0$ below.

The latitudinal cross sections at 15-17 LGT illustrate the behavior of the evening vortex: 1) the focus (X' -- it vanishes, Z -- it is maximum), regardless of the orientation of Y_{SE}, is located at $\phi' < 80°$ and never is displaced toward the geomagnetic pole; 2) distinct compression of the focus is observed from $\phi' \sim 77°$ for $Y_{SE} < 0$ to $\phi' \sim 79°$ for $Y_{SE} > 0$. This displacement is responsible for the change of sign of variation of the horizontal component at the Godhavn Observatory in connection with SSIMF.

Such slight latitudinal displacement of the focus of evening current vortex cannot explain the observed variations of Z in the polar region when the sign of Y_{SE} changes. The change of the sign of Z from positive for $Y_{SE} < 0$ to negative for $Y_{SE} > 0$ is attributed to replacement of the current band in the daytime sector with westward current for $Y_{SE} < 0$ by a current band from the morning to evening hours with eastward current for $Y_{SE} > 0$. What apparently takes place is not simple displacement of the current jet as Y_{SE} changes directions, but the weakening of one current and the strengthening of the other. This problem will be discussed in greater detail in future publications.

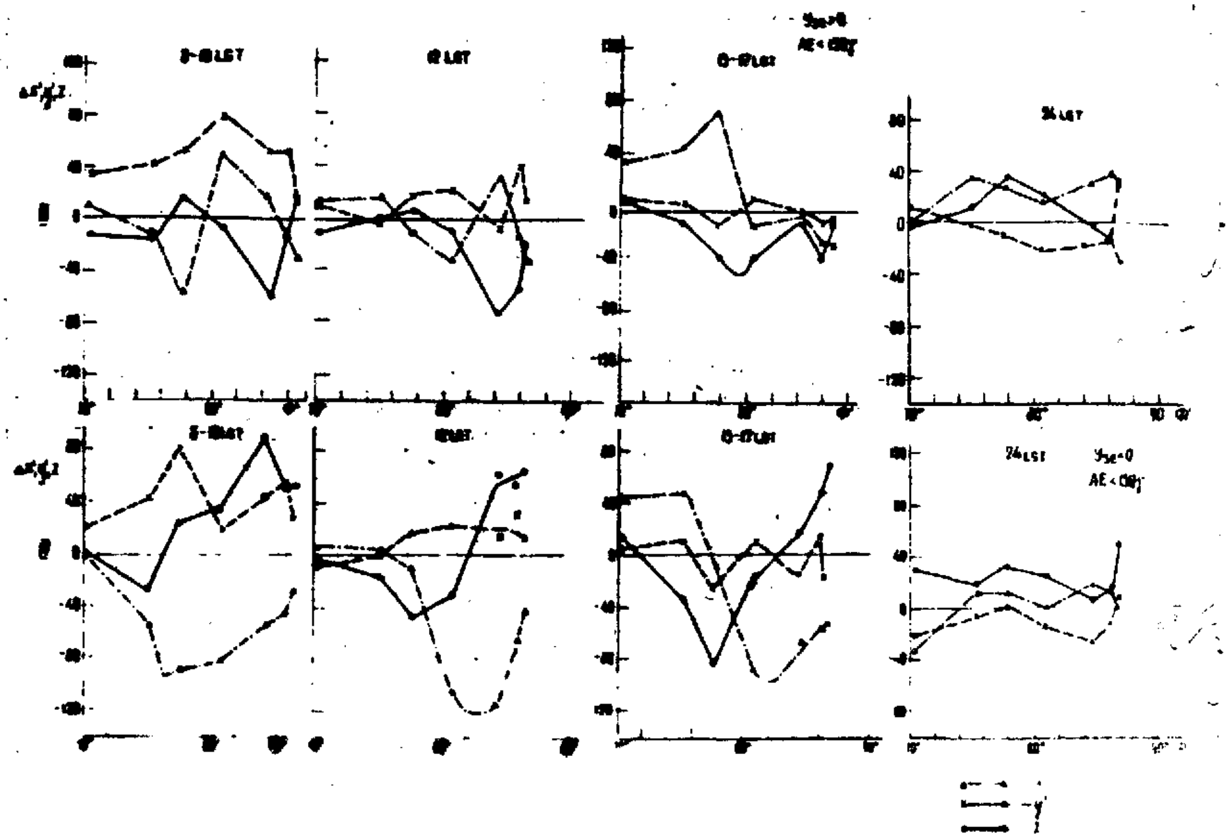


Figure 6. Same as Figure 5. Days with AE < 150 γ are used. $Y_{SE} > 0$ above, $Y_{SE} < 0$ below.

The distribution of currents illustrated in Figures 1-4 agrees satisfactorily with the results of measurements of electric fields in the Northern Hemisphere during the summer aboard the satellite OGO-6 [14]. The orbital plane of the satellite is centered on the 18-6^h meridians, local time. The intensity of the electric field that approaches the polar region from morning to the evening side is maximum in this cross section during the evening hours for /9
$Y_{SE} < 0$ and during the morning hours for $Y_{SE} > 0$. On the assumption that Hall currents flow in the ionosphere, this will lead to compression of the currents flowing in the direction of the sun, at $\sim 18^h$ for $Y_{SE} < 0$ and $\sim 6^h$ for $Y_{SE} > 0$. Such compressions actually exist in Figures 1-4. The current system proposed

in [14] diverges significantly from the one described in this work on the daytime side of the polar region. The currents in this region flow approximately along the parallel and their direction changes sharply at $\phi' \sim 78°$, whereas in [14] the entire region from $\phi' > 78°$ is covered by uniform current layer, in which the current flows from the night side to the day side. It should be pointed out that the existence of longitudinal convective plasma motions on the day side, which change sign at $\phi' \sim 80°$, was discovered in [15, 16].

The current system for $Y_{SE} > 0$ is similar to the distribution of current in the polar region, determined in [17] for the initial stage of the storm of 1-2 April 1964.

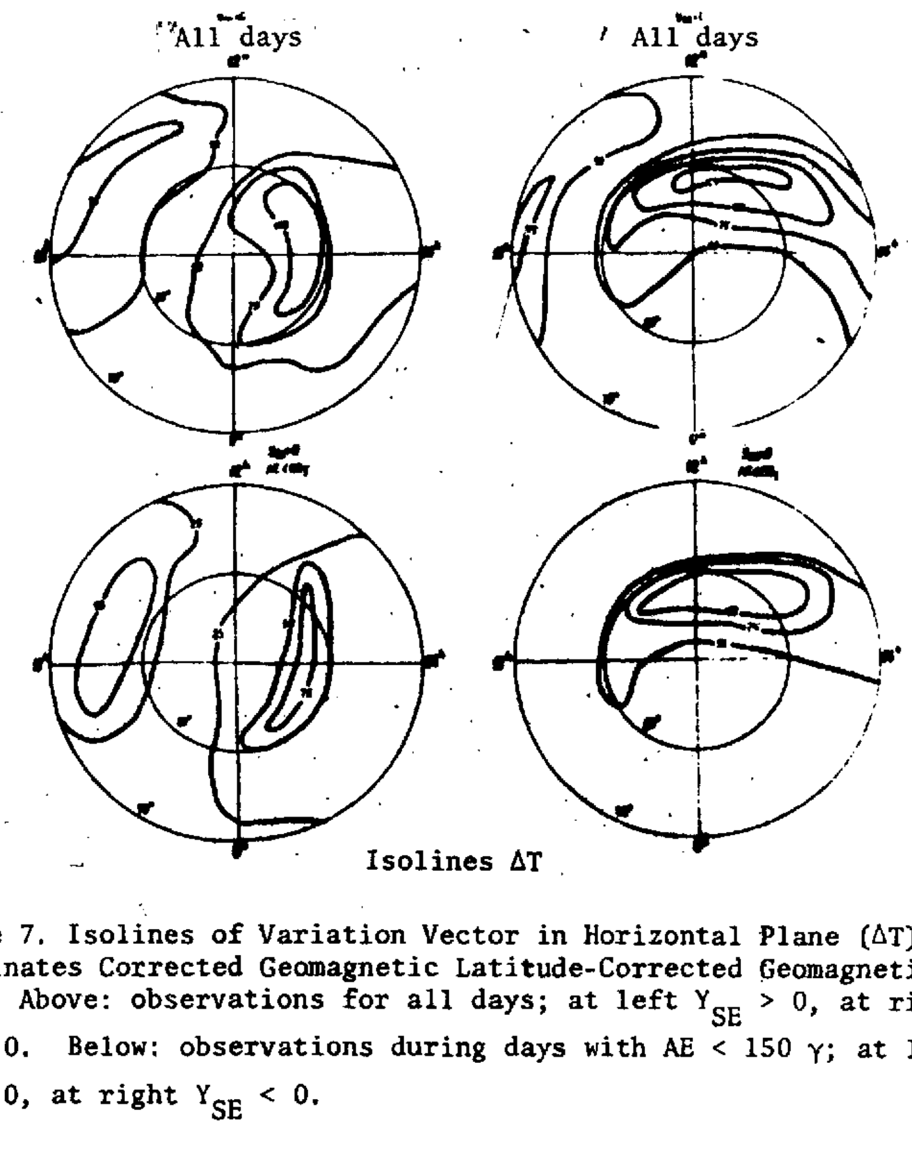


Figure 7. Isolines of Variation Vector in Horizontal Plane (ΔT) in Coordinates Corrected Geomagnetic Latitude-Corrected Geomagnetic Time. Above: observations for all days; at left $Y_{SE} > 0$, at right $Y_{SE} < 0$. Below: observations during days with AE < 150 γ; at left $Y_{SE} > 0$, at right $Y_{SE} < 0$.

Shown in Figure 7 in the polar coordinates "corrected geomagnetic latitude--local geomagnetic time" are the intensity isolines of the variation vector in the horizontal plane (ΔT) for four investigated groups of days according to the data of seven observatories at $\phi' > 70°$. These data are additional proof of the existence of current compressions during the summer in the polar region, the configuration and location of which are determined by the sign of Y_{SE} of the IMF component.

The authors express their gratitude to J. Vette for making available the results of observations of the interplanetary magnetic field from the satellite IMP-3.

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